AI-assisted rapeseed meal loading system

DIH² 2nd Open Call

Introduction
Consortium: Manufacturing Company

SIA BIOVENTA is largest biodiesel production and transshipment company in Baltic states operating since 2004

Bio-Venta is exporting its products Biodiesel

(FAME – fatty acid methyl esters), rapeseed cake,

glycerol and fertilizer (potassium sulphate) to

European countries and Russia, main target market

being Scandinavian countries.

Turnaround last year 2020 was 102,8 M EUR, 66 employees.

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Introduction
Consortium: Tech Provider

SIA ASYA

Operating since 2018, reg. no. 40203171916, Latvia

Team of award winning Deep Learning scientists of top universities of the region.

Raised 0.5 mil investement from venture capital firms.

Successful products deployed for multiple manufacturing businesses.

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Problem Description

Application Type: Manufacturing

Main Process: Loading side-products in heavy trucks

Generalised problem title: Blockage of the rapeseed meal loading system and hazards to workers.

Generalised Problem Description

In the process of pressing rapeseed oil for the manufacturing of biodiesel and other products, a rapeseed meal is produced as a side product. It is a fine-grained substance that can be used to feed animals on farms. The substance is stored in large 5-ton containment units and then loaded into heavy trucks using a conveyor line and a mechanical tube that can be lowered within the bed of a truck. Normally these trucks are 13.6 meters long, and it is not possible to load rapeseed meal by lowering the tube just at a single location. The operator observes the process and as soon as the pile reaches the level of the truck`s bed, the operator raises the tube and signals the driver to move forward. Then the operator signals the driver to stop, lowers the tube, and continues the process. At the same time, the substance continues to flow through the tube because stopping the conveyor belt causes problems upstream in the production line. When the operator is fatigued, as this process often happens also during night shifts and all day, the tube may not be lifted soon enough and rapeseed meal can block it, causing losses in operation as the conveyor must be stopped and blockage cleaned. The loading location is in an open air and very dusty environment, causing health hazards to the operator.

* The content of this slide aims to provide the necessary inputs to evaluate the proposal according to the following Relevance Requirements in the Guide for Applicants: H-PR-01 and H-PR-02
* Some tips in the Annex of this Short Template (Diagrams in Slides 24 and 25)

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TTE Problem Description
Current Factory Scenario

Base Successful Production Cases	Challenging Production Cases
he successful base operation involves careful manual work. Each truck load is completed in 5-10 minutes with around 6 iterations of lowering and raising the loading tube in a truck bed and communication with the truck driver. The successful operation does not involve any blockages in the tube or spilled goods outside the truck bed. Successful operation allows continuous loading of the trucks and stopping conveyor only in between changing the trucks.	There are a number of challenges in establishing a successful loading scenario: • Inexperienced or fatigued operators could raise the loading tube too late, causing blockage and stoppage of the the conveyor. It would also require cleaning of the tube and conveyor, which is an expensive, dirty, and time-consuming work. • As the loading dock is in the open air during winter time, operators often get sick and cause losses for the company. • Inexperienced or fatigued truck drivers may not hear the signals to move and stop again, causing expensive blockage of the loading tube. • Manual work on the control panel is inefficient and an automatic control system would improve the loading speed.

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Proposed Solution

Smart Factory Platform Type(s): Robotic automation, AI-based control
Smart Factory Platform Operation(s): Loading of the rapeseed meal
Mandatory Peripherals: Cameras, Ultra-sonic sensors, Visual signal board, Control units
Title: AI-assisted system for controlling the process of loading rapeseed meal into trucks and effective communication with the truck driver.

Solution Overview

The system based on Deep Learning model that uses ultrasonic sensors and cameras helps to automatically load rapeseed meal in to heavy trucks. It tracks and controls the robotic tube for pouring in the substance and communicates with the truck driver to synchronize the truck movement with the loading process. It pours the substance up till the truck bed, then the truck is ordered to move ahead, and the next pile is poured. All meanwhile the conveyor belt is continuously operating pouring the substance. The system also monitors the movement of the truck driver. If the truck driver is not responding, a warning is sounded. And if it is still stationary, then an emergency stop is automatically issued to avoid blocking of the tube. Sensor information is aggregated using FIWARE ORION. Events of and warnings are also issued using FIWARE PERSEO system. Using sensor information, it would be possible to estimate and measure the capacity and speed of the process to optimize loading procedures. Latest statistics of the loading operations would be displayed for the needs of the factory manager as a custom WireCloud widget.

* The content of this slide aims to provide necessary inputs to evaluate the proposal according to the following Relevance Requirements in the Guide for Applicants: H-SR-01 and H-SR-02
* Supporting slides can be found in the Annex of this Short Template (Slides 29 and 30)

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Proposed Platform Design (1/2)
System of Systems View
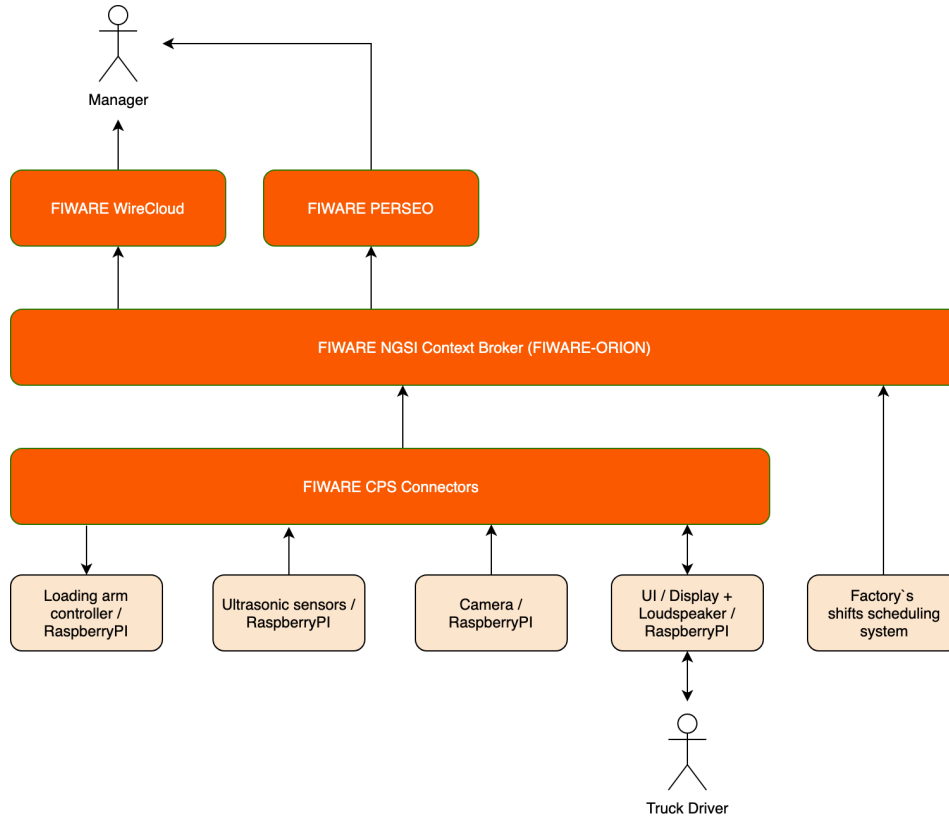
Proposed Platform Design (2/2)
FIWARE-Ready Smart Factory Platform

The system will consist of a sensor fusion model to estimate the amount of pored substance within each pile to retract the loading tube and order movement of a truck. It will also have a separate model to estimate the location and movement of a truck in response to the commands issued by the control system. It will also feature sensor fusion using ultrasonic proximity sensors and vision systems. The system will use a number of FIWARE components starting from the basic FIWARE Orion context Broker and ending with custom widgets in FIWARE WireCloud and custom actions in FIWARE PERSEO.

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Technology Readiness Level

The system is currently in TRL 5 as both the technology that consists of deep learning models and application to packaging have been tested in multiple visits to the factory floor. The goal is to reach TRL 7 and implement multiple sets of smart assistants on at least 4 locations in the factory. Deep learning model required for the task previously has been published in scientific journals by the technology provider and has successfully been applied for segmentation of damaged wooden planks in another project.

* The content of this slide aims to provide necessary inputs to evaluate the proposal according to the following Relevance Requirements in the Guide for Applicants: H-SR-01 and H-SR-04

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Excellence Requirements

(Soft) Quality Requirements

Target Scenario
Envisioned Factory Deployment

Targeted Base Successful Production Case for the envisioned Factory Deployment
The system should reduce the stop of the conveyor belt of the rapeseed meal loading process from 5-10 events to a maximum of 1-2 events in a month. It should also improve the loading speed of rapeseed meal by at least 10%. It should also reduce the human labor in servicing the system down to 10%, thus reducing most of the health hazards associated with manual operation.

Main Risks Identified (High / Medium /Low Impact)
Some of the risks of successful deployment: • The environment might be too dusty for ultrasonic and camera-based sensors to work properly (low impact). It could be mitigated by regular manual cleaning or automatic cleaning using compressed air valves. • The accuracy of the models might not be sufficient to control the loading arm (medium impact). It could be mitigated by more labelled data samples, more sensors, or other types of sensors. • The truck driver may not respond to the control signals (medium impact). It could be mitigated by more strict operational procedures and automatic emergency systems to prevent blocking of loading tubes. • Improvements in loading speed might not be worth the investment in the new system (medium impact). Even if the loading speed stays the same, the system will reduce expenses of manual labor and reduce health hazards for factory workers.

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Target Scenario
Goals, KPIs and Experimental Methodology

Goal <Id, Name>	Achievements (KPIs)	Assessment	Risks
1. Control of the loading tube and truck driver using shadow-mode and remote controls	Maximum of 1-2 events stopping in a month. 0 sick days due health hazards associated with open-air operations and dust.	Examine event logs and sick leave registers.	Sensors or models not precise enough or environment too dusty for sensors to operate correctly.
2. Automatic control of the loading tube and truck driver	Reduce the human labour in servicing the system down to 10% of full-time requirement.	Examine work reports and time-sheets.	Low skilled manual operators might not want to move to other roles in the factory.
3. Optimization of the loading process speed	Improve the loading speed of rapeseed meal by at least 10%.	Examine logistics reports and sales reports.	Shipping service companies might not adjust fast enough to new capacity of the loading system. The system might operate with minimal human interaction, but the speed might not be greater than that of a human operator.

* The content of this template aims to provide the necessary inputs to evaluate the proposal according to the following Relevance
   Requirements in the Guide for Applicants: S-ER-02

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Preliminary Ideas on the Exploitation Plan
Manufacturing Company

AI-assisted rapeseed meal loading system is a first step towards specifically designed solutions to automate and increase the production speed and quality of processes that have been manually controlled up to date. Bio-diesel manufacturing consists of many hazardous processes that can be automated using AI-based models. Oil press process and purification process is already highly automated, but processes like loading, unloading of goods, and logistics could benefit from automation systems.

* The content of this slide aims to provide the necessary inputs to evaluate the proposal according to the following Relevance Requirements in the Guide for Applicants: S-ER-03

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Preliminary Ideas on the Exploitation Plan
Technology Providers

The SIA ASYA technology provider consists of a team of scientists coming from the research laboratories of Riga Technical University and Ventspils University. So far, the company have successfully delivered AI-based systems to B2B clients like Scope Technologies, ZippyVision, Giraffe360, CatchBox, and others. The company's researchers have also published a number of scientific papers that show the cutting-edge capabilities of the team. The latest business strategy is to find AI-based solutions that could be licensed to a large number of similar customers. The AI-assisted rapeseed meal loading system would be licensed to other biodiesel and cooking oil manufacturers that have the same problems.

* The content of this slide aims to provide the necessary inputs to evaluate the proposal according to the following Relevance Requirements in the Guide for Applicants: S-ER-04

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Use Case Template

Use Case Template (1/5)
Challenging Production Case

Title: Rapeseed meal loading system

Short Description:
Rapeseed meal is loaded into heavy trucks using a controllable loading tube, conveyor belt that is moving the substance and an audible communication signals to instruct truck driver.
Input in the system is the side product of biodiesel, rapeseed meal. It is stored in large 5000ton containment units and then is transported by a conveyor belt to the loading tube. The output of the system is a fully loaded 25-ton heavy truck. The most challenging parts of the process are as follows:
1. Prevent tube blockage by mismanagement of manual controls caused by fatigue of the loading operator or a truck driver. Cleaning the loading tube and conveyor could cost up to 10 000 euros per incident.
2. Manual operation of the loading tube and communication with the truck driver using audible signals are inefficient, slowing down the loading process.
3. The environment is hazardous to the loading operator as it is highly dusty and the draft of the winds often causes sick leave, especially during the cold winter months.

Required Smart Factory Capabilities

Real-time Supervision

Computer-based Optimisation at Asset, Process, Plant, and/or Business Levels

Main Actors, Systems, and Factory Assets Involved

- The loading system operator, factory manager, truck driver, rapeseed containment units, rapeseed containment units, the system of rapeseed conveyor belts, the system of rapeseed loading tube

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Use Case Template (2/5)
Proposed Solution

Solution Title and Short Description

Title: AI-assisted rapeseed meal loading system

The new system would work using an array of ultrasonic sensors, 1-8 RGB cameras and AI-based model for sensor fusion and control of the rapeseed loading tube and signals to a truck driver. This system automatically would order a truck driver to drive forward under the loading tube using large visual and audio signals like the ones used in automated car wash. The system would also verify the compliance of a truck driver by detecting movement of a truck and its position relative to the loading tube. Then the system would automatically lower the loading tube, then depending on the size of the rapeseed meal pile retract it and then order movement of a truck again. The system would receive sensor readings and camera feed using the FIWARE context broker. The manager would be able to monitor the system using a custom widget in FIWARE WireCloud. The expected performance of the system should prevent expensive blockages of the loading tube and also prevent sick leave from the loading operator due to hazardous working conditions. It should also improve the loading speed by at least 10%.

The content of this template aims to provide the necessary inputs to evaluate the proposal according to the following Relevance Requirements in the Guide for Applicants: H-SR-03

Use Case Template (3/5)
Summary

Targeted Capability	Smart-assitant Responsibilities	Digital Platform Responsibilities		Custom/Legacy System Responsibilities
		Standardised (Powered by FIWARE)	Custom	
Automation of the rapeseed meal loading process	Automation of the loading process and communication with a truck driver.	Using context of sensor readings, visual scene segmentation and communication state with the truck driver maintain the control of the process.	PyTorch-based AI models for sensor fusion, segmentation and control of the system.	-
Optimization of the rapeseed meal loading process	Monitoring efficiency of the loading process.	Provide statistics and event- based notifications to the factory manager	Unsupervised models to extract information that would be useful for the process optimization.	-

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Use Case Template (4/5)

Information Sheet – AI-assisted rapeseed meal loading system

Main Features:

- Is the system already in the factory? – No
- If not, Is it clear which system will be used? - Yes
- Main Technical Specifications – Active sensor-based system using AI models and easy to use HCI
- Main Responsibilities for the smart factory platform – Automatic control of the loading process and improvement in the loading speed
- Main responsibilities for the physical environment - Truck driver must comply with the commands issued by the system
- Resources to be consumed – Electricity, human resources

- **FIWARE-Ready - Yes**
- **Other Interfaces - No**

Controllable loading tube in a truck bed (notice very dusty environment)

Current system just have single signal light and manual control

Signal to move

FIWARE NGSI
The system provides and consumes NGSI context data. Main attributes for NGSI entity – distance to truck bed, position of a truck, amount loaded, loading tube state, conveyor belt state.

Additional Comments:

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Use Case Template (5/5)

Information Sheet –
Truck driver

Role Description (Highlights):

What?
A truck driver is responsible for collecting and moving the rapeseed meal to the target destination using a heavy truck with an open bed.

Why?
Currently, trucks are still operated by a human driver and the rapeseed meal loading system using a stationary tube with movement only in a single dimension upward or downward. To spread the substance evenly and to prevent blockage of the tube, a truck driver must comply with orders of the system.

How?
A truck driver responds to visual and audio signals issued by the AI-assisted rapeseed meal loading system by moving the truck forward and backward with incremental steps.

Additional Comments: -

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Use Case Template (5/5)

Information Sheet –
Maintenance operator of the loading system

Role Description (Highlights):

What?
The loading system maintenance operator is responsible for ensuring the uninterrupted and correct operation of the loading system.

Why?
An human operator is necessary to access if all of the ultrasonic sensors and cameras are clean enough for operation and there are no obstructions for the operations of a truck driver.

How?
Operator routinely checks the state of the sensors, cleans them using compressed air, or installs automatic system for cleaning sensors that get dirty too soon.
In an emergency, the operator would receive notification from FIWARE PERSEO if the system is unable to continue operations safely because of malfunctioning sensors.

Additional Comments: -

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Use Case Template (5/5)

Information Sheet –
Manager of the loading process

Role Description (Highlights):

What?
The manager of the loading process is responsible for ensuring an efficient load process and preventing misuse of the loading system.

Why?
A skilled and experienced manager is necessary to evaluate how much the loading speed could be increased based on the operation of the system.

How?
Using the system, the manager accesses the statistics in FIWARE WireCloud to evaluate the loading speed.

Additional Comments: -

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